

Preventive Maintenance on CNC Machines Using the OEE Method to Reduce Downtime at PT. MTAT**David Rakes¹, Muhammad Arif², Agus Setiawan³, Kerina Putri Nasution⁴, Yudi Prastyo⁵**

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Keywords

Downtime, Overall Equipment Effectiveness (OEE), Pareto Analysis

Abstract

This study examines the performance of CNC machines at PT MTAT Indonesia from January to March 2023. Monthly production data, machine uptime, defect rates, and non-productive periods were collected to assess Overall Equipment Effectiveness (OEE). This study aims to analyze the effectiveness of preventive maintenance of CNC machines at PT MTAT Indonesia using the Overall Equipment Effectiveness (OEE) method to reduce downtime. This study uses monthly data from January to March 2023, including production uptime, defect rates, and non-productive periods, to calculate OEE. The analysis showed that the CNC machines achieved an average OEE of 86.52%, surpassing the global standard of 85%, indicating high efficiency and quality. The study used Pareto analysis to identify the main causes of downtime, finding technical and maintenance issues as the main contributors. By addressing these factors, PT MTAT Indonesia can further improve machine efficiency and productivity. This study contributes to this field by providing a comprehensive analysis of CNC machine maintenance and proposing strategies for continuous improvement.

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E-mail: davidrakes98@gmail.com**INTRODUCTION**

In the manufacturing industry, sustainability and operational efficiency are key to achieving high competitiveness and profitability. PT. MTAT Indonesia, located on Jababeka Raya Street, Cikarang, focuses on producing motor vehicle components. One of the company's flagship products is the Pully Assy made from JFE steel. To ensure quality and production effectiveness, they use advanced Computer Numerical Control (CNC) machines.

Although CNC technology offers high precision and efficiency, the main challenge is maintaining these machines at optimal effectiveness levels (Nallusamy, 2016). One way to evaluate and improve machine effectiveness is through Total Productive Maintenance (TPM), assessed using the Overall Equipment Effectiveness (OEE) method (Pandey, Malviya, & Jain, 2019). OEE is a crucial tool for identifying and eliminating waste in the production process, ensuring machines operate at maximum performance.

This study aims to analyze the total maintenance effectiveness of CNC machines at PT. MTAT Indonesia using the OEE method. Data was collected from January to March 2023, including information on total production, loading time, the number of defective products (NG), and CNC machine downtime. This data was then processed to calculate the three main components of OEE Availability Rate, Performance Rate, and Quality Rate.

The Availability Rate measures the efficiency of machine operation time compared to downtime. The Performance Rate indicates the efficiency of the machine in producing output compared to its maximum capacity. The Quality Rate reflects the proportion of products meeting the established quality standards.

The analysis results show that the average OEE of CNC machines at PT. MTAT Indonesia during this period was 86.52%, which is above the global standard of 85%. However, there is variability in the OEE components, indicating areas needing further improvement, particularly concerning downtime due to technical issues and maintenance.

The study also uses Pareto diagram analysis to identify the main factors causing downtime. The results indicate that technical issues and maintenance are the largest contributors to downtime, accounting for 50.6% and 37% of the total downtime, respectively.

By understanding and addressing these factors, PT. MTAT Indonesia can enhance the operational effectiveness of CNC machines, reduce waste, and improve overall productivity. This study not only provides an overview of the current conditions but also offers strategic directions for continuous improvement in the CNC machine maintenance process at the company.

THEORETICAL FOUNDATION

Definition of Preventive Maintenance Preventive maintenance is a maintenance approach aimed at preventing machine breakdowns and failures before they occur. The primary goals of preventive maintenance are to enhance equipment reliability, extend machine lifespan, and reduce downtime (Lee et al., 2020). By conducting preventive maintenance, potential issues can be identified and resolved before they cause significant damage (Al-Duais, Mohamed, Jawa, & Sayed-Ahmed, 2022).

CNC Machines CNC (Computer Numerical Control) machines are computer-controlled machines used to perform various operations such as cutting, milling, drilling, and engraving on materials (Enokela & Anfofun, n.d.). These machines are crucial in the manufacturing industry due to their ability to produce products with high precision and efficiency (Budastour, Alazmi, Alshehry, & Karam, 2019). The performance of CNC machines heavily depends on the condition of their components and control systems, making proper maintenance essential (Molenaar & Ingrassia, 2024).

Overall Equipment Effectiveness (OEE) Overall Equipment Effectiveness (OEE) is a performance indicator used to measure the overall effectiveness of production equipment. OEE is the product of three main factors: Availability, Performance, and Quality. OEE is calculated using the formula: $OEE = Availability \times Performance \times Quality$ measures the actual operating time compared to the planned operating time.

- a. Performance measures the machine's operating speed compared to the ideal speed.
- b. Quality measures the number of good products compared to the total production.

Using OEE, companies can identify areas that need improvement and take preventive actions to enhance the effectiveness and efficiency of the machinery (Stamatis, 2017). To calculate the OEE value, each of these components must be known.

Availability is the ratio between operation time and loading time. To calculate machine availability, the following values are needed:

- a. Operation time
- b. Loading time
- c. Downtime

The formula for calculating Availability is:

$$Availability = \frac{Operation\ time}{Loading\ time} \times 100\%$$

Loading time is the total working hours for the production process minus planned downtime, such as machine setup and other activities.

$$Loading\ time = \text{raining time} - \text{planned downtime}$$

Planned downtime is the time allocated for maintenance (scheduled maintenance) or other management activities.

$$Operation\ time = \text{loading time} - \text{downtime}$$

In other words, operation time is the loading time or the available time for production minus downtime. Downtime is the period when the machine should be operating but is not producing output due to disruptions such as equipment failures (Bokrantz, Skoogh, Ylipää, & Stahre, 2016). Downtime includes operational stops due to breakdowns, setup procedures, adjustments, and other factors (Shagluf, Longstaff, & Fletcher, 2014).

Performance Rate The performance rate considers factors that cause the production process to deviate from the maximum speed. For example, operator inefficiency in using the machine (Colledani et al., 2014). The performance rate is calculated by multiplying the number of products by the time required to complete one unit, divided by the operation time, and then converted to a percentage.

$$\text{Performance rate} = \frac{\text{jumlah produk}}{\text{waktu siklus per unit operation time}} \times 100\%$$

Quality Rate The quality rate describes the machine's ability to produce products that meet the standard. The quality rate is the ratio between gross product and total reject. The formula for calculating the quality rate is:

$$\text{Quality rate} = \frac{\text{Gross product} - \text{total reject}}{\text{Gross product}} \times 100\%$$

Six Big Losses Six Big Losses are six categories of losses caused by low machine efficiency. This calculation is used to determine the overall effectiveness value of OEE. According to Wauters & Mathor (2022), Six Big Losses are divided into three categories that hinder machine effectiveness (Singh, Khamba, & Singh, 2021):

1. **Downtime Losses** Downtime losses are losses due to the loss of production time that should be available, including:
 - a. **Breakdown Losses** Losses due to machine breakdowns requiring repair or component replacement. Breakdown losses are measured by calculating the time needed to restore the machine to functioning condition.
 - b. **Breakdown Losses** = (Total Breakdown time)/(Loading time) x 100%
 - c. **Set-up and Adjustment Losses** Losses due to changes in operating conditions such as shift changes, product changes, and operational adjustments. This time is not included in planned downtime.
 - d. **Set-up and adjustment losses** = $\frac{\text{Total set-up and adjustment}}{\text{Loading time}} \times 100\%$
2. **Speed Losses** Speed losses occur when the machine loses speed or cannot operate at the planned maximum speed, including:
 - a. **Reduced Speed Losses** Losses due to the difference between the ideal speed and the actual operating speed. Causes can include excessive workload or worn-out machine components.
 - b. **Idling and Minor Stoppages Losses** Losses that occur when operating machines face obstacles such as jams or idling.
3. **Quality Losses** Quality losses are losses that occur because the machine produces products that do not meet quality standards.

Impact of Downtime in Production Downtime refers to periods when machines or equipment are not operating due to failures or maintenance (Nwanya, Udofia, & Ajayi, 2017). Unplanned downtime can negatively impact production, including reduced output, increased costs, and delayed deliveries. Therefore, reducing downtime through preventive maintenance is crucial to maintaining smooth operations and increasing productivity (Kanike, 2023).

Implementing Preventive Maintenance with OEE Implementing preventive maintenance using the OEE method involves the following steps:

1. **OEE Measurement:** Conduct initial OEE measurement to determine the baseline performance of the machine.
2. **Data Analysis:** Analyze OEE data to identify root causes of downtime and areas needing improvement.
3. **Maintenance Plan Development:** Develop a specific preventive maintenance plan based on OEE data analysis results.

4. Maintenance Execution: Perform preventive maintenance actions according to the planned schedule.
5. Evaluation and Continuous Improvement: Evaluate maintenance results and make continuous improvements to enhance OEE and reduce downtime.

By applying OEE-based preventive maintenance, companies can improve operational efficiency, extend machine lifespan, and minimize downtime (Agung & Siahaan, 2019).

The novelty of this research lies in the integration of OEE measurements with Pareto analysis to provide a targeted approach to identify and reduce the causes of downtime on CNC machines. The research also compares performance with international standards, offering a unique perspective on maintaining high efficiency levels in a specialized manufacturing context.

RESEARCH METHOD

Data Collection

This study collected data comprising: (1) Working hours and machine downtime over a month, (2) Production data from CNC machines over a month, and (3) Defective products produced by CNC machines over the same period, which serve as the research object.

Data Processing

The data analysis technique used in this research is Overall Equipment Effectiveness (OEE), which functions as a measurement tool in the implementation of Total Productive Maintenance (TPM) to maintain equipment in ideal conditions. The following steps are taken to measure the effectiveness of the equipment:

Calculation of Availability Ratio (%): The availability ratio describes the utilization of available time for machine or equipment operation. It is the ratio between operation time and loading time, where operation time is obtained by subtracting equipment downtime from loading time. The formula used to measure the availability ratio is:

$$\text{Availability} = \frac{\text{Operation time}}{\text{Loading time}} \times 100\%$$

Explanation:

- 1) Operation time is the duration the equipment operates.
- 2) Loading time is the time available for production (per period).

Calculation of Performance Ratio (%): The performance ratio is the ratio of the quality of produced products multiplied by the ideal cycle time against the available time (operation time). The formula used to measure the performance ratio is:

$$\text{Performance rate} = \frac{\text{jumlah produk}}{\text{waktu siklus per unit operation time}} \times 100\%$$

Explanation:

- 1) Output is the total number of products that can be processed by the machine.
- 2) Ideal cycle time is the theoretical or ideal production cycle time.
- 3) Operating time is the duration the equipment operates.

Calculation of Quality Ratio (%): The quality ratio represents the ability of the equipment to produce products that meet standards. The formula used to measure the quality rate is:

$$\text{Quality rate} = \frac{\text{Gross product} - \text{total reject}}{\text{Gross product}} \times 100\%$$

Explanation:

- 1) Product amount is the number of products produced.
- 2) Defect amount is the number of defective products in the production system.

Calculation of Overall Equipment Effectiveness (OEE): Overall Equipment Effectiveness (OEE) is obtained by multiplying these main ratios to determine the effectiveness of machine usage. The OEE value can be calculated using the formula:

$$\text{OEE}(\%) = \text{Availability}(\%) \times \text{Performance Rate}(\%) \times \text{Quality Rate}(\%)$$

OEE analysis is derived from calculating availability, production effectiveness, and quality level, compared against TPM standards to determine machine effectiveness. The JIMP standard for ideal TPM index is:

- 1) Availability (AV) $\geq 90\%$
- 2) Production Effectiveness (PE) $\geq 95\%$

- 3) Quality Rate (RQ) $\geq 99\%$
- 4) Overall Equipment Effectiveness (OEE) $\geq 85\%$ (Ideal OEE: $(0.90 \times 0.95 \times 0.99) \times 100\% = 85\%$)

In this study, respondents were represented by a sample taken through nonprobability sampling (non-random sampling), using two methods:

- 1) Incidental sampling: Anyone who happens to meet the researcher can be used as a sample if considered suitable as a data source. This means that in sample collection, the researcher selects respondents from every customer who comes to the service location during the questionnaire distribution.
- 2) Convenience sampling: Distributing questionnaires to customers who are transacting at the dealer.

RESULTS AND DISCUSSION

Data Collection PT. MTAT Indonesia, based on Jalan Jababeka Raya, Cikarang, is a manufacturing company focused on producing motor vehicle components. One of its main products is the Pully Assy, made from JFE type iron raw material.

January Production Data

Below is the information regarding the production output generated by the CNC machining machines during January.

Table 1 January Output Data

Line	Shift 1	Shift 2
Total Production (Pcs)	6464	6380
Loading Time (Minutes)	9690	9438
Total NG (pcs)	16	12
Downtime (Minutes)	725	711

Source: PT. MTAT Indonesia, January 2023

February Production Data

The total production data for February 2023 by CNC milling machines is as follows:

Table 2 February Output Data

Line	Shift 1	Shift 2
Total Production (Pcs)	5936	5165
Loading Time (Minutes)	8790	7608
Total NG (pcs)	17	8
Downtime (Minutes)	695	568

Source: PT. MTAT Indonesia, February 2023

March Production Data

The total production output for March 2023 by CNC milling machines is as follows:

Table 3 March Output Data

Line	Shift 1	Shift 2
Total Production (Pcs)	8195	7966
Loading Time (Minutes)	11862	11464
Total NG (pcs)	22	5
Downtime (Minutes)	793	786

Source: PT. MTAT Indonesia, March 2023

Total Production Output for Three Months (January 2023 - March 2023)

Table 4 Total Output for Three Months

Month	Total Production (Pcs)	Loading Time (Minutes)	Total NG (pcs)	Downtime (Minutes)
January	26279	38766	53	2663
February	22376	32808	40	2319
March	32576	46756	39	2865

Source: PT. MTAT Indonesia, January-March 2023

Data Processing

This data can be processed to determine the effectiveness level of the CNC machines. Before calculating the Overall Equipment Effectiveness (OEE), it is necessary to compute the Availability Rate, Performance Rate, and Quality Rate as initial steps.

1. Availability Rate

The Availability Rate is an indicator that shows how efficiently the available time for operational activities of the machine or equipment is utilized. The main focus is on the effective use of production time compared to downtime. The formula used to calculate the Availability Rate is:

$$\text{Availability} = \frac{\text{Operation time}}{\text{Loading time}} \times 100\%$$

Table 5 Availability Rate Calculation

Month	Loading Time (Minutes)	Downtime (Minutes)	Availability Rate
January	38766	2663	93%
February	32808	2319	92%
March	46756	2865	93%

Source: Data Processing 2024

2. Performance Rate

The Performance Rate is a comparison that shows the equipment's efficiency in producing goods. This formula is based on the output produced by the machine compared to its capacity.

$$\text{Performance rate} = \frac{\text{jumlah produk}}{\text{waktu siklus per unit operation time}} \times 100\%$$

Table 6 Performance Rate Calculation

Month	Output	Capacity Machine	Performance Rate
January	26279	28000	93.85%
February	22376	24800	90.16%
March	32576	33600	96.96%

Source: Data Processing 2024

3. Quality Rate

The Quality Rate is a comparison that reflects the equipment's efficiency in creating products that meet established standards. When calculating the quality rate, factors such as the number of products produced and their quality level are important, with an emphasis on products that meet expected quality standards.

$$\text{Quality rate} = \frac{\text{Gross product} - \text{total reject}}{\text{Gross product}} \times 100\%$$

Table 7 Quality Rate Calculation

Month	Total Production (Pcs)	Total NG (pcs)	Quality Rate
January	26279	53	99.80%
February	22376	40	99.82%
March	32576	39	99.88%

Source: Data Processing 2024

Data Processing Results

The data processing results show a high level of CNC machine effectiveness at PT. MTAT Indonesia during the period from January to March 2023.

Table 8 Data Processing Results

Month	Availability Rate	Performance Rate	Quality Rate	OEE
January	93%	93.85%	99.80%	87.38%
February	92%	90.16%	99.82%	82.82%
March	93%	96.96%	99.88%	89.36%

Source: Data Processing 2024

The average OEE of CNC machines at PT. MTAT Indonesia over these three months is 86.52%, which is higher than the world standard of 85%.

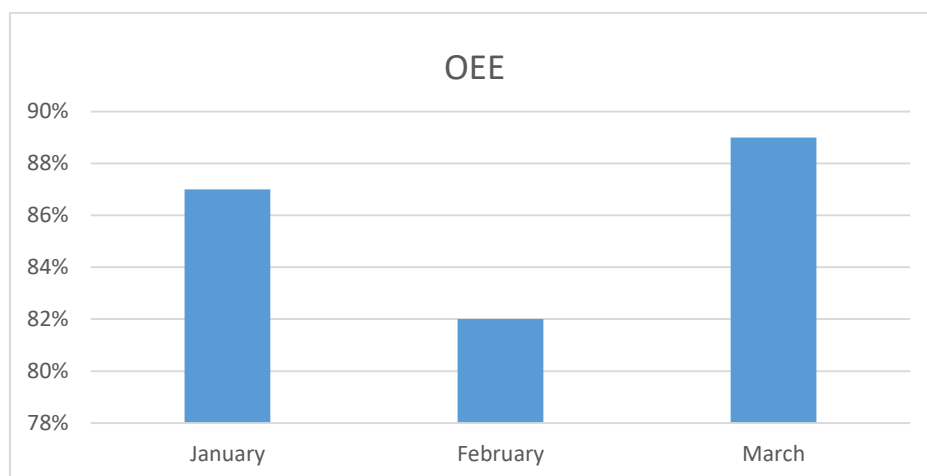


Diagram of Overall Equipment Effectiveness Calculation

OEE decreased from 87% in January to 82% in February. This 5% decline could indicate specific issues that need to be investigated further.

The decrease in OEE can be attributed to several factors such as:

- a Machine Availability (Availability): There might be an increase in machine downtime caused by unscheduled maintenance or sudden breakdowns.
- b Machine Performance (Performance): There could be a decrease in machine operation speed or a bottleneck in the production process.
- c Production Quality (Quality): There might be an increase in defective products or products that require rework.
- d Recovery in March: OEE increased back to 89% in March, indicating an improvement from the issues that occurred in February. This increase shows that the corrective actions taken in February successfully addressed the problems causing the OEE decline.
- e Average OEE: The average OEE over these three months is $(87\% + 82\% + 89\%) / 3 = 86\%$. This is still within a good range, but it shows that there is room for improvement, particularly in February.

Recommended Steps:

- a Investigate Causes: Conduct an in-depth analysis to find the exact reasons for the OEE decline in February. This could include downtime data analysis, production process inspection, and product quality review.
- b Process Improvement: Implement improvements in the identified problem areas. If the issue is machine availability, ensure a better maintenance schedule. If the issue is performance or quality, review and optimize the production process.
- c Continuous Monitoring: Continuously monitor OEE to ensure that the implemented improvements remain effective and to detect issues early.

By following the above steps, it is expected that OEE can be maintained or even improved in the following months.

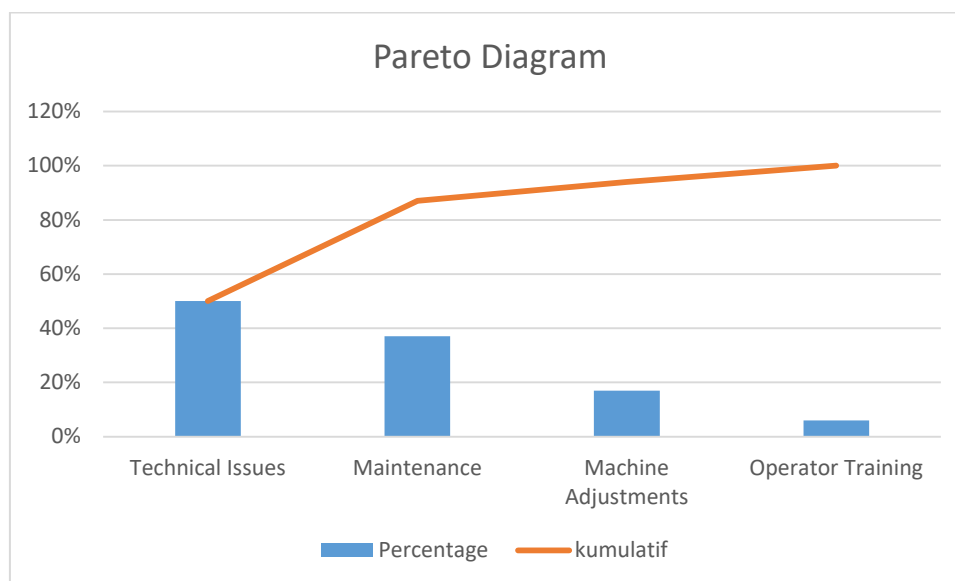
Pareto Chart Analysis

To identify the main issues affecting machine effectiveness, a Pareto chart analysis is used. This analysis helps to identify the key factors contributing to downtime and the reduction in CNC machine performance. Based on the collected data, downtime due to technical issues and maintenance are the biggest factors causing a decline in machine Effectiveness.

Table 9 Main Causes of Downtime

Cause	Downtime Duration (Minutes)	Percentage	kumulatif
Technical Issues	1347	50%	50%
Maintenance	986	27%	77%
Machine Adjustments	442	17%	94%
Operator Training	198	6%	100%
Total	2973	100%	

Source: Data Processing 2024



Primary Cause Downtime Image

The issues related to this table involve downtime in operations or processes. This downtime is caused by several primary factors:

1. Technical Issues: Contribute to 50.6% of total downtime, totaling 1347 minutes.
2. Maintenance: Contribute to 37% of total downtime, totaling 986 minutes.
3. Machine Adjustments: Contribute to 16.6% of total downtime, totaling 442 minutes.
4. Operator Training: Contribute to 7.4% of total downtime, totaling 198 minutes.

Problem Resolution:

1. Technical Issues: To reduce downtime caused by technical problems, steps such as enhancing preventive maintenance, regularly repairing faulty equipment, and implementing better monitoring technology to detect issues before they cause significant downtime are necessary (Selcuk, 2017).
2. Maintenance: Downtime due to maintenance can be minimized by scheduling maintenance activities, prioritizing preventive maintenance, and ensuring adequate spare parts are available to reduce unproductive repair time (Aransyah, Rosa, & Colombo, 2020).
3. Machine Adjustments: To reduce downtime from machine adjustments, it is crucial to improve machine setup processes, ensure efficient adjustment procedures are established, and train operators to perform adjustments correctly (Rick et al., 2023).
4. Operator Training: Downtime caused by operator skill deficiencies can be minimized through comprehensive and regular training. Operators should be trained in machine operation, handling common issues, and safety procedures to work more effectively and reduce the likelihood of errors.

By identifying the primary causes of downtime and implementing appropriate resolution strategies for each factor, the company can enhance operational efficiency and reduce losses incurred due to production stoppages.

While previous research has extensively explored the application of OEE in various industries, there is limited research that focuses specifically on CNC machines in the context of motor vehicle component manufacturing. Additionally, there is a gap in research that integrates Pareto analysis with OEE data to determine and address the specific causes of downtime.

CONCLUSION

PT. MTAT Indonesia achieved an average OEE of 86.52% over these three months, demonstrating strong performance despite a decline in February. Through thorough analysis, process improvement implementations, and continuous monitoring, the company aims to sustain or improve OEE in the upcoming months. By taking these steps, PT. MTAT Indonesia can maximize its operational efficiency, reduce production downtime losses, and enhance overall quality and productivity.

RECOMMENDATIONS

Root Cause Investigation: Conduct a thorough analysis to identify the root causes of the OEE decline in February, including downtime data analysis, inspection of production processes, and product quality review. **Process Improvement:** Implement improvements in the identified problem areas. If the issue relates to machine availability, ensure a better maintenance schedule. If it concerns performance or quality, review and optimize production processes. **Continuous Monitoring:** Continuously monitor OEE to ensure the implemented improvements are effective and to detect any issues early on.

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